NEXT STEPS IN DEEP SPACE
Next Steps in Exploring Deep Space

A Cosmic Study by the International Academy of Astronautics

- A vision for the future and a description of what could be done
- Not a strategic plan or a product of any national space agency
- Human space exploration as a global enterprise

A logical and systematic roadmap

- To establish a permanent human presence in space
- For conducting scientific exploration of the solar system and the Universe
- With a goal to land humans on Mars sometime in the next 50 years
- Evolutionary architecture emphasizing intermediate destinations of scientific and programmatic value: Stepping stones to Mars

A work in progress

- Final report to be submitted in early 2004
- All ideas and contributions are welcomed
To Discover - the exploration imperative
- Expand the frontiers of human experience
- Fulfill the basic human need to always move forward
- Inspire, educate, and engage our youth and the public

To Understand - the scientific imperative
- Knowledge and understanding of what surrounds us in space
- Answers to fundamental questions of our origins and destiny
- Advance and sustain human learning and technological progress

To Unify - the political imperative
- Toward a global endeavor without national boundaries
- Toward mutual achievement and security through challenging enterprise
- Toward human utilization of the solar system
SCIENCE GOALS
Ages-old human questions lead to scientific challenges

Where do we come from?
- Determine how the universe of stars and planets began and evolved
- Determine the origin and evolution of Earth and its biosphere

What will happen to us in the future?
- Determine the nature of the space environment and cosmic hazards to Earth
- Determine the potential for human permanent presence in space

Are we alone in the universe?
- Determine if there is or ever has been other life in the Solar System
- Determine if there are life-bearing planets around other stars

How do we meet these challenges?
- Conduct a systematic, scientific exploration of the Solar System
- Conduct astronomical observations of the Universe beyond
From Scientific Challenge to Science Objectives (1)

**Where do we come from?**

*Determine how the Universe of stars and planets began and evolved*

- Search the Universe across the spectrum and to the beginnings of time
- Observe the process of planetary system formation in the galaxy
- Survey the diversity of small bodies in the Solar System

*Determine the origin and evolution of the Earth and its biosphere*

- Search for evidence on the origin of the Earth-Moon system
- Search for samples from the earliest episodes in the history of the Earth
- Obtain evidence on the Sun’s history and its effect on Earth through time
From Scientific Challenge to Science Objectives (2)

What will happen to us in the future?

* Determine the nature of space and any cosmic hazards to Earth
  - Determine the history of asteroid and comet impacts on Earth
  - Determine the bulk properties and internal structures of NEO’s

* Determine the potential for permanent human presence in space
  - Determine the form, amount, and origin of lunar ice
  - Determine the utility of NEO’s as potential resources for materials in space
  - Determine the feasibility of *in situ* resource production on Mars
Are we alone in the universe?

**Determine if there is or ever has been other life in the Solar System**
- Determine the geological and climatological histories of Mars
- Determine the history of water and its form and distribution on Mars
- Search for evidence of life on Mars and in the subsurface ocean of Europa

**Determine if there are planets with life around other stars**
- Search for terrestrial planets around other stars
- Search for evidence of life through observations of extrasolar planets
From Science Objectives to Exploration Objectives

Science objectives lead to the following exploration objectives…

- Conduct astronomical investigations using large space observatories
- Conduct scientific exploration of the Moon, Mars and (later) Europa
- Conduct a scientific survey of a diverse suite of Near Earth Objects

…at four destinations which can be reached by humans in the next 50 years

- Sun-Earth Libration Point L2, the Moon, NEO’s, and Mars

…which can lead to a permanent human presence in space

- Robotic exploration leads to a human outpost at L2
- Capabilities grow to encompass visits to NEO’s and the Moon
- Human exploration of Mars can be achieved by the middle of this century
Destinations and Architectures
Guiding Principles of the Architecture

Mars is the goal
- Intermediate destinations and local architectures are established with this ultimate goal in mind

Science-driven
- Address key questions of broad scientific and public interest
- Science goals and objectives provide context for destinations, capabilities, and technology investments

Stepping-stone approach
- Logical progression to successively more difficult destinations
- Minimize incremental investments to maintain progress; adjust destinations if necessary to help manage cost and risk

Utilize existing or planned capabilities
- Avoid requiring major new technology developments early in the program
- Solar electric and nuclear electric propulsion, along with improved chemical propulsion, can meet early transportation needs

Separate cargo and crew
- Minimize crew flight time by using minimum-mass transfer vehicles
- Cargo, supplies, and exploration equipment travel in advance of crew using highly efficient electric propulsion
Destination: Sun-Earth L2

A constellation of space telescopes

- Survey the Universe across the spectrum and to the beginning of time
- Observe the process of planetary system formation in the galaxy
- Search for terrestrial-like planets around other stars
- Search for evidence of life in the spectrum of extra-solar planets

Exploration architecture

- Initial step: A “Deep Space Shuttle” providing access from LEO
- Human outpost for assembly and maintenance of observatories
- Preparation for later interplanetary voyages
- Trade study: Humans at L2 vs. other locations (with robotic transfer of telescopes)
Destination: Moon

**Lunar outposts for exploration on the Moon**

- Search for evidence of the origin of the Earth-Moon system
- Determine the history of asteroid and comet impacts on Earth
- Obtain evidence of the Sun’s history and its effects on Earth through time
- Search for samples from the earliest episodes in the history of the Earth
- Determine the form, amount, and origin of lunar ice

**Exploration architecture**

- A proving ground for development of surface systems, habitats, and technologies
- Deep Space Shuttle provides the necessary transportation capability
- Possible use of lunar resources to enhance access to other destinations
- The Moon may not be in the “critical path” to Mars
Destination: Near-Earth Objects

Field exploration of asteroids

- Survey the diversity and composition of NEO’s
- Determine the bulk properties and internal structures of NEO’s
- Determine utility of NEO’s as potential resources for materials in space and how we might mitigate future Earth impacts

Exploration architecture

- An intermediate deep space destination to test a human Mars expedition
- Cargo (via SEP) and crew travel separately from L2 or other gateway, to minimize crew flight time
- High degree of commonality with L2 infrastructure
Destination: Mars

**Outposts on Mars - robots and humans working together**

- Determine the geological and climatological histories of the Mars
- Determine the history of water and its distribution and form on Mars
- Search for evidence of past and current life on Mars
- Establish a permanent human presence on Mars - the most Earth-like planet

**Exploration architecture**

- Cargo travels separately via SEP or NEP, crew rendezvous at or near Mars
- All exploration equipment and habitats arrive before crew for risk reduction
- Phobos/Deimos a possible first destination in Martian system to reduce incremental investment; high commonality with NEO infrastructure
Next Steps Architecture

- Sun-Earth L2
- Moon
- Near-Earth Asteroids
- Mars
- Phobos/Deimos
- Cargo (SEP)
- Crew
- Cargo (SEP/NEP)
Summary and Next Steps

- Incorporate ideas and concepts from this workshop
- Assess and refine the architecture
- Identify key trade studies for the future
- Engage the public and key policy makers
“A journey of a thousand miles…

… begins with a single step"

- Lao Tsu